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ABSTRACT

This booklet gives a brief history of the metric system up to the present time. A detailed explanation of the international system of units (SI units) for length, area, volume, mass, temperature, and time is included. Also included are five check-up tests with answers for the measures of length, area, volume, and weight, as well as tables of all metric prefixes and of practical units for commerce and trade. A third section contains general guidelines for teaching the metric system with specific directions for spelling, punctuation, and use of metric symbols. The fourth section contains classroom activities, lists of recommended materials, and instructions for student-made learning aids. (JBW)

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The Long Journey toward Metric Adoption

THE CONTROVERSY concerning the standardization of weights and measures in the United States is as old as the nation itself. The Europeans who settled America brought with them the tools, customs, and practices of their respective homelands, whose units of weights and measures were based on the customs and commercial dealings of the province or local community. This had produced a great variety of units of measurement, which in turn had resulted in variations in the standards of weights and measures both within as well as among the different European countries. Because of the diversity of the customs and cultural backgrounds among the early colonists in America, there was no uniformity of weights and measures during the embryonic stage of this country's development. However, the nation's founders recognized the need for standards, and they provided Congress with the constitutional power to fix the standards of weights and measures.

During the first eighty years following the adoption of the Constitution, emphasis was given to achieving a uniformity of weights and measures among the states and, to some degree, with other nations. On many occasions during this period, serious consideration was given to the question of whether the metric system should be adopted as the standard for the United States. The principal arguments presented by various groups and individuals at this time, both for and against the adoption of the metric system, have become classics and are still being used in current debates on the adoption of the metric system.

Although it appears (at the time of this writing) that the metric question may soon be answered, the following brief historical summary will help to explain why the metric controversy has continued for almost 200 years.

The First American Proposal for Standardizing Weights and Measures

In 1790, following the ratification of the Constitution, President George Washington directed the First Congress of the United States

to consider the problem of setting standards for weights and measures. The Congress reacted to this appeal by requesting Thomas Jefferson, secretary of state, to prepare a proposal for establishing such standards. (A unique situation existed in the United States at that time. Historically, monetary systems were generally based on a country's system of weights. This was not so in the United States, for in the 1780s the Continental Congress had established a decimal monetary system, with the dollar as the base unit. But even though the Continental Congress had been given the power to establish standards for weights and measures, it had failed to do so. Thus, the United States had a standardized decimal monetary system that bore little or no relationship to the units of measure in use at the time. Jefferson had supported the adoption of a decimal monetary system because of the ease in calculating with decimal units; therefore, it is not surprising that he also recommended a decimal-based system for weights and measures.)

In his report to Congress, Jefferson emphasized the need for establishing an absolute standard for length based on some invariant physical phenomenon to be found in the universe and easily accessible to all nations. Uniformity throughout the world would thus be assured and any nation could calculate the standard without having to depend on any other nation. Scientific information based on measurements could also be accurately recorded and transmitted to scientists in any country throughout the world. Jefferson further proposed that such a standard was to be based on the principle of the pendulum. His proposal specified (1) that the pendulum should be a cylinder of iron located at sea level on latitude 45° and protected in such a way that the temperature would not vary at any time during the year and (2) that the cylinder should be of such a length that the swing from one end of its arc to the other would take one second.

Jefferson's plan was to use this standard of length, based on the pendulum, for adjusting to uniform standards the customary English units then in use. He proposed that the basic units of weight and volume be directly related to the basic unit of length. In this way, all other standard units for weight, volume, and other measurements could be easily and consistently established. He also proposed that the new system of weights and measures be based, like the monetary system, on the decimal system to help simplify calculations. He further suggested that the old familiar names should be retained for the new basic units and that the size of the new units should be kept close to the size of those already in use. This would help reduce the problems that might arise with the introduction of a new system.

In Jefferson's system (see table 1) the basic unit of length was the *foot*. The standard length of the foot was one-fifth the length of the iron cylinder used as a pendulum. The subdivisions and multiples of the foot were established by dividing and multiplying the basic unit by powers of ten.

The basic unit of weight was the *ounce*. The standard for the ounce was the weight of one cubic inch of rainwater.

TABLE 1
UNITS IN JEFFERSON'S MEASUREMENT SYSTEM

Linear Units	Weight Units
1 mile = 10 furlongs	1 hogshead = 10 kentals
1 furlong = 10 rods	1 kental = 10 stones
1 rod = 10 decads	1 stone = 10 pounds
1 decad = 10 feet	1 pound = 10 ounces
1 foot	1 ounce
1 inch = $\frac{1}{10}$ foot	1 double-scruple = $\frac{1}{10}$ ounce
1 line = $\frac{1}{10}$ inch	1 caret = $\frac{1}{10}$ double-scruple
1 point = $\frac{1}{10}$ line	1 minim = $\frac{1}{10}$ caret
	1 mite = $\frac{1}{10}$ minim

Jefferson reported that the monetary system could be easily adjusted to be proportional to the system of weights and measures. This would form a completely consistent system of weights, measures, and coinage for the nation.

Congress discussed the merits and implications of Jefferson's plan for six years. However, no new legislation resulted. No doubt the conservative members of Congress refused to accept the recommendations of the report because they considered that the decimal-based units were too different from the customary units in use and would not be readily accepted by the public. This same argument for maintaining the present measurement system is still being used today by the antimetric factions. Another reason for the lack of action on the Jefferson plan was that the *metric* system, being introduced by France at the same time, was being considered as an international standard for all commercial nations.

The Early Development of the Metric System

In 1790 the United States, England, and France were all working toward the establishment of uniform standards of weights and measures. If the political relations between these three nations had been more congenial, no doubt both England and the United States would have become metric nations along with France.

At the same time that Jefferson was asked to prepare his report to the Congress, the French Academy was undertaking an investigation to determine a uniform standard for all weights and measures. The Royal Society of London was invited to join the Academy in this investigation but did not accept. The Academy's study was based on the same three basic principles as Jefferson's plan, which were the same principles advanced by other mathematicians and scientists throughout the world:

1. The standard unit for length should be derived from some universally accessible, invariant physical standard.
2. The basic units for volume and mass should be derived from the basic unit for length, so that all basic units are directly related to each other.
3. The specified units for each measure should be based on decimal ratios.

The French Academy soon established the *meter* (metre) as the standard unit for length. A meter was defined as one ten-millionth of the length of an arc from the North Pole to the equator.

The meter was used to derive all the other units of the metric system. The Academy worked not only to make the system compulsory for France but also to have it accepted by all nations.

In 1795, the revolutionary government of France officially adopted the metric system and passed laws that made the system compulsory. In an effort to have the system accepted internationally, copies of the provisional standards of the meter and kilogram were sent to several countries, including the United States. But the strained political relations between France and the United States (the United States had refused to take sides in the dispute between England and France) prevented the metric standards from being accepted in the United States. In fact, relations were so badly strained that the United States was not invited to send representatives to the international gathering convened in Paris in 1799 for the formal presentation of the new metric system of measurement.

Acceptance of the metric system was a slow process even in France, where it was required by law. Because the French government had not provided copies of the standards for the local government agencies and because copies for commercial use were very scarce, the law could not be enforced. Also, as could be expected, the public was reluctant to change from their familiar measurement system to the new and unfamiliar metric system. Although acceptance was not complete, the system was implemented in France. Under the original provisional standards, time and angle measure were also divided decimally, and for a brief time during the French

Revolution, even the calendar was adapted to the metric system, so that France had a ten-day week. The decimal time clock was not accepted by the public, and the ten-day week was soon discarded because of the strong opposition from religious groups who claimed that a change from the biblical seven-day week was an act of heresy.

In 1812 Napoleon abrogated the provision that made the use of the metric system compulsory and established a new measurement system that combined the metric standards with the old familiar names for units and with the old ratios of weights and measures. This new and complicated system was retained for almost thirty years. However, the conglomeration of units made the use of the system so confusing and impractical that the need for another change to a simpler system was quite evident. In 1837, therefore, the French government passed a law that again made the metric system the official system of measurement and made its use compulsory beginning in 1840.

With the acceptance and use of the metric system in France came the rapid acceptance of the system by other countries throughout the world. By 1880 more than twenty nations had adopted the system, and by 1900 thirty-nine of the world's leading commercial countries had changed to the metric system.

The Development of Measurement Standards in the United States

While the controversy over the establishment of a standard system of weights and measures was taking place in France, England, and other European countries, the same problem was being considered by the Congress of the United States. In 1799, thirteen years after the adoption of a decimal monetary system and nine years after the ratification of the Constitution, which granted Congress the power to establish a uniform system of weights and measures, Congress still had not legislated any uniform standards. Congress had accepted neither the comprehensive system proposed by Jefferson nor the metric system proposed by France. During this year Congress did pass the Surveyor Act, which required the surveyor of each port to make a semiannual inspection of all weights and measures used in collecting custom duties. However, since there were no federal standards, the law could not be enforced.

Little was done to resolve the problem during the next twenty years. In 1817 Congress again requested a comprehensive report relative to the establishment of a standard system of weights and measures, and in 1821 Secretary of State John Quincy Adams sub-

mitted his *Report upon Weights and Measures*. This report was the first systematic consideration of the metric system by the United States government. Adams presented an eloquent and exhaustive treatment of the pros and cons of both the metric system and the customary system in reference to the conditions that existed at that time. The report was so complete and well presented that it was used for many years by persons on both sides of the metric controversy to document and support their arguments.

In his report, Adams presented four possible means of achieving a standardized system of weights and measures:

1. Adopt the metric system as proposed by France.
2. Reinstate and standardize the old English system of weights, measures, and coins.
3. Establish a new, combined system of metric and customary units by adapting some of the units and underlying principles of each system to the other.
4. Maintain the customary units of weights and measures but establish a fixed standard for all units.

Adams had his own preference:

> Adams' own preference was a two-stage approach. First, he would have the familiar English units standardized and approved without change. Later, he would have the President begin negotiating with France, Britain, and Spain to establish a uniform international measurement system.
>
> The recommendations were in keeping with the times. By 1821 most states in the Union had already enacted laws providing for weights and measures and specifying the English customary units. At a time when the constitutional rights of the states were just beginning to be examined by the Supreme Court, any attempt to upset these laws by imposing the metric system might have been very disturbing. Mr. Adams was aware of this point. He was also aware that the most pressing need was for agreement on uniform standards of any sort.
>
> In addition, he stressed international harmony of measurement. The preponderance of American trade at that time was still with Britain, and the U.S. was bounded on one side by British Canada and on the other by Spanish possessions. He therefore deemed it wise to consult both Britain and Spain before making any such radical change as adopting the metric system. [National Bureau of Standards 1971, pp. 11–12]

Congress took no action on the Adams report. In fact, it was another eleven years before any federal standards of weights and measures were established. The metric question was not reconsidered for an even greater period of time, more than forty years after Adams made his presentation to Congress.

In 1828 a law setting a standard of weight for coinage, based on the Troy pound previously obtained from Great Britain, was passed. After almost fifty years from its beginning as a new nation, the United States had finally adopted its first standard of weights and measures.

In 1830 Congress gave authority to the secretary of the treasury to make a study of the standards of weights and measures used by the customhouses. The survey showed there was great variation in the standards. Because of the survey's results, the secretary of the treasury established in 1832, without further authority from Congress, standards for the yard, the avoirdupois pound (which was based on the Troy pound used for coinage), and the bushel. He further directed that copies of these federal standards be distributed to all customhouses.

Congress supported this action by the Treasury Department and in 1836 also resolved that these standards be distributed to all the states. The distribution of standards to state governments was carried out, but the task took almost fifteen years to complete.

Very little happened in the United States between 1840 and 1863 to force the nation to reevaluate its position on the metric system. The standardization of weights and measures did not become a national issue again until the 1860s. By this time the international acceptance and use of the metric system had expanded to such magnitude that the United States could no longer ignore its importance. As in previous years, the political climate of the 1860s was not favorable for the necessary collaboration with Britain and France for establishing international standards. Civil war in the United States and strained diplomatic relations with both Britain and France forced the topic of uniform standards of weights and measures to a very low position in the hierarchy of critical issues. Some important decisions regarding measurements were made, however, and some progress toward international standardization was achieved during this time.

Several events helped to move the United States closer to the acceptance of the metric system. In 1863 the National Academy of Sciences, a group that would be strongly in favor of adopting the metric system, was founded. In 1864 Congress established a Committee on Coinage, Weights, and Measures as a standing committee of the House of Representatives. This committee existed for eighty-two years (1864–1946); it was responsible for enacting several important legislative bills on the standards for weights and measures and helped to establish the National Bureau of Standards. In 1866 Congress made the use of the metric system legal in the United States, directed the secretary of the treasury to furnish each state

with a set of standard metric weights and measures, and directed the postmaster general to furnish each post office handling foreign mail with a postal balance calibrated in grams.

It was assumed by members of the House Committee on Coinage, Weights, and Measures that this legislation would encourage the teaching of the metric system in the schools and hasten its acceptance as the preferred system of measurement by the majority of the American people. Although the laws did not produce the widespread change of attitudes toward the metric system that the originators of the bills had anticipated, some gains for the prometric movement were achieved. New educational literature that explained the metric system was widely distributed, along with tables of English-metric equivalents. The new laws also helped strengthen the position of the United States in international negotiations concerning advanced standards of weights and measures.

A need for improved international standards of metric units prompted the calling of an international conference on this subject in 1872 and again in 1875. In 1875 representatives of seventeen nations, including the United States, signed the *Convention du Mètre* (Treaty of the Meter), which provided for an International Bureau of Weights and Measures. The main task of the bureau was to construct and verify new, improved standards of metric units. The new standards were completed in 1889, and prototypes of the standards were distributed to all the nations that had signed the Treaty of the Meter. Acceptance of the prototype meters and kilograms implicitly established the metric system as the official international system of weights and measures. Although not all nations recognized this action, it was accepted by almost all nations in the Western Hemisphere.

In 1893 the United States Treasury Department published a bulletin that declared that the prototype meter and kilogram would from that time on be considered the nation's fundamental standards of length and mass. This action meant that the units of the English customary system would be redefined by designating a yard as a fractional part of the meter and a pound as a fractional part of the kilogram. This proclamation was not made official by an act of Congress, but neither was any objection to this decision raised by Congress. Thus, the redefinition of the units of weights and measures in terms of metric standards was allowed to take place.

The House Committee on Coinage, Weights, and Measures was almost successful in its efforts to secure governmental adoption of the metric system. In 1896 the House of Representatives passed a bill requiring the adoption of the metric system. However, it later voted to reconsider this action, and the bill was sent back to the

committee for further study. As is often true, efforts to revive the bill failed, and it subsequently died in committee.

The House committee issued another report in 1902 advocating the adoption of the metric system. Congress did not act on this recommendation. About this time opposition to metrication began to gain momentum, and debate occurred even among members of the House committee. Debate on governmental adoption of the metric system continued for five years, but the prometric faction lost ground. In 1907 the House committee refused to support the pending legislation for metrication. With this action efforts to enact legislation to adopt the metric system stopped and did not resume for almost ten years.

For the next twenty years the polarized prometric and antimetric forces carried out an extensive propaganda program to inform the general public of their respective arguments in an attempt to win its support. Several professional groups, such as the American Metric Association and the American Institute of Weights and Measures, were founded during the early 1900s to provide support for both the prometric and the antimetric activities.

The early 1930s marked the end of a long period of active support for the adoption of the metric system. The Great Depression was a significant reason, since it created a shortage of money for campaigning or for implementing a changeover if the metric system had been adopted.

After World War II the question of metrication again gained popularity, and activities for enacting legislation resumed once more.

In 1948 the National Council of Teachers of Mathematics published its Twentieth Yearbook, which was directed entirely to a discussion of the advantages of the metric system and presented arguments for its adoption. The yearbook also emphasized the need for teaching the metric system.

Increased interest in science education in the 1950s, particularly after the launching of Sputnik, put pressure on Congress to increase the study of measurement standards.

The late 1950s and the 1960s included many significant "milestones" in the movement toward adoption of the metric system. A few of these events are briefly described in the following paragraphs.

The Committee on Science and Astronautics was established as a standing committee of the House of Representatives in 1958. During this same year the customary units of pound and yard were *officially* defined in terms of metric units. Also, for the first time, the pound and yard were standardized with the same units used

by Australia, Canada, New Zealand, South Africa, and Great Britain.

In 1960 the Eleventh General Conference on Weights and Measures, which included the United States, adopted a new international standard for the meter. The new standard was based on the wavelength of the orange-red line of the spectrum of the krypton 86 atom and replaced the original "meter bar," which had been officially adopted as the standard following the Treaty of the Meter. The conference also officially renamed the modernized metric system as the Systéme International d'Unités (International System of Units), or SI. This action acknowledged the wide acceptance of the modernized system and encouraged unanimous acceptance by all industrial nations of the world.

In 1965 Great Britain announced its plan to convert to the metric system over a ten-year period.

In 1968 Congress directed the secretary of commerce to conduct over a three-year period a comprehensive study that would determine the advantages and disadvantages of increased use of the metric system in the United States.

Measurement Standards in the 1970s

The Report on the U.S. Metric Study was submitted to Congress in 1971. The report recommended—

1. that the United States change to the metric system by adopting a coordinated national program;
2. that a plan of action be decided by Congress and that a target date of ten years after the beginning of the conversion program be established as the time when the United States shall have become a predominantly, though not exclusively, metric nation;
3. that a coordinating body be established for directing the conversion program;
4. that early emphasis be given to educating every schoolchild and the public at large to understand the metric system and to think in metric terms;
5. that changeover costs should in general "lie where they fall";
6. that the government make a firm commitment to the goal of metric conversion.

In 1972 the United States Senate passed on a voice vote the Metric Conversion Act of 1972. However, no action was taken by the House on this bill.

In 1973 many metric bills were submitted for consideration. The main features of these bills were combined, and in October the House Subcommittee on Science, Research, and Development submitted the metric conversion bill (H.R. 11035) to the House Rules Committee. The Senate version of the metric conversion bill (S. 100) was introduced in January 1973. No action was taken on either bill in 1973.

In May 1974 a motion to suspend the rules to consider the House metric conversion bill (H.R. 11035) without amendments was defeated by a five to three margin. This defeat is a setback for metric legislation, but it does not mean that the issue is dead. However, no further action on metric legislation was considered by the Ninety-third Congress.

Even without formal legislation the United States is going metric. General Motors Corporation, Ford Motor Company, International Business Machines, Rockwell International, and International Harvester Company are just a few of the many American companies that have begun their own metric conversion programs.

At the time of this writing there are only five nations in the world other than the United States who have not officially committed themselves to a metric changeover program: Brunei, Burma, Liberia, the Yemen Arab Republic, and the Yemen People's Republic.

The U.S. Department of Health, Education, and Welfare announced in 1973 that all new nutritional information appearing on food labels will be in metric units. Many states and cities have installed highway signs with metric units. The U.S. Department of Agriculture began using metric units along with customary units in reporting major crop yields in May 1974. The National Weather Service plans to begin using the metric system for reporting weather information soon after Congress enacts metric legislation. Many other examples could be cited, but these should be convincing that the move toward metric standards and the everyday use of metric units is well on the way to becoming reality in the 1970s.

Education is the key to a successful metric conversion program. Even though Congress has not yet passed a metric conversion bill, it has given educators specific directions to work toward improving the teaching of the metric system and has provided federal assistance for the development of new materials and programs.

The Elementary and Secondary Education Act (H.R. 69), which was passed by a wide margin and signed into law by President Ford in 1974, contains a section (404) entitled "Education for the Use of the Metric System." Paragraph 2 of subsection (a) states, "It is the policy of the U.S. to encourage educational agencies and institutions to prepare students to use the metric system of meas-

urement with ease and facility as a part of the regular education program."

Every teacher needs to know something about the metric system. Activities, materials, and suggestions for effective teaching of the metric system follow in subsequent chapters.

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2

The SI Units of Metric Measurement

WHAT IS a metric system of measurement? It is a system of weights and measures in which the unit of length is the meter. In metric systems the basic units—and the larger and smaller units derived from those basic units—are related to each other in *decimal* fashion, that is, by multiples and submultiples of ten. Only the modernized metric system, called the international system of units (Systéme International d'Unités) and the most widely accepted metric system in use throughout the world, will be considered here.

The international system of units (SI units) is built on a foundation of seven base units, one for each of the following quantities: length, mass, temperature, time, electric current, amount of substance, and luminous intensity. Other units are derived from combinations of these base units. In this book only the units of measurement for those quantities usually included in the elementary and junior high school programs—length, area, volume (capacity), mass (weight), temperature, and time—will be discussed.

Length

Since length is the easiest measurement concept for children to understand, it is the first concept of measurement introduced in a school program. The base SI unit for length is the *meter*. (This unit is also spelled *metre*, but it is recommended that the -er spelling be used for nontechnical work and be considered the accepted spelling for the elementary program. However, children should be made aware that the -re spelling is considered correct also and is used in technical work.)

The meter is a little (about 10 percent) longer than a yard. Since this unit is not convenient for measuring the length of very small things, submultiples of the meter are used. Because the metric system is a decimal-based system, the first submultiple of the meter is one-tenth (0.1) of the meter. This unit is called a *decimeter*. (1 meter = 10 decimeters and 1 decimeter = 0.1 meter.) Two jumbo paper clips placed end to end have a total length of approximately one decimeter.

The next submultiple of the meter is one-hundredth (0.01) of the meter. This is called a *centimeter*. (1 meter = 100 centimeters and 1 centimeter = 0.01 meter.) The width of a jumbo paper clip at its widest point is approximately one centimeter. Note that a centimeter can also be thought of as one-tenth of a decimeter, that is, 10 centimeters = 1 decimeter.

The third submultiple of the meter is a *milli*meter, which is one-thousandth (0.001) of the meter. (1 meter = 1000 millimeters and 1 millimeter = 0.001 meter.) Th~ wire used to make a jumbo paper clip is approximately one millimeter in diameter. A millimeter can also be thought of as one-tenth of a centimeter (10 millimeters = 1 centimeter) and as one-hundredth of a decimeter (100 millimeters = 10 centimeters = 1 decimeter).

The prefixes *deci-*, *centi-*, and *milli-* are also used with other SI units to show the same relationships of one-tenth, one-hundredth, and one-thousandth of the unit.

To measure lengths much longer than a meter, units that are multiples of ten times the meter are used. The first multiple of the meter is ten meters, or a *dekameter*. A dekameter is a little (about 10 percent) longer than the length of the ten-yard marking chain

used in football. The next two multiples of the meter are one hundred meters, a *hectometer*, and one thousand meters, a *kilometer*. A hectometer is about 10 percent longer than a football field. A kilometer is about 0.6 of a mile. The relationships between the units larger than a meter should be easy to identify: 10 dekameters = 1 hectometer and 100 dekameters = 10 hectometers = 1 kilometer.

The prefixes *deka-*, *hecto-*, and *kilo-* are also used with other SI units to show the same relationships of ten times, one hundred times, and one thousand times the unit.

The SI metric units can be represented by symbols that are accepted internationally and that are exactly the same in every country using the SI units. It is important to note that symbols are not abbreviations. Therefore, a symbol is not followed by a period, except at the end of a sentence.

Table 2 summarizes the foregoing units of metric length, along with their correct SI symbols and a pronunciation key. Notice that the symbols for these units are all lowercase letters. The units that are italicized are those that are most often used in practical situations.

TABLE 2
UNITS OF LENGTH

Unit Name	SI Symbol	Value in Meters	Pronunciation Key
kilometer	km	1000 m	*kill*-o-meter
hectometer	hm	100 m	hec-toe-meter
dekameter	dam	10 m	*deck*-a-meter
meter	m	1 m	me-ter
decimeter	dm	0.1 m	dess-ie-meter
centimeter	cm	0.01 m	sen-ta-meter
millimeter	mm	0.001 m	*mill*-ie-meter

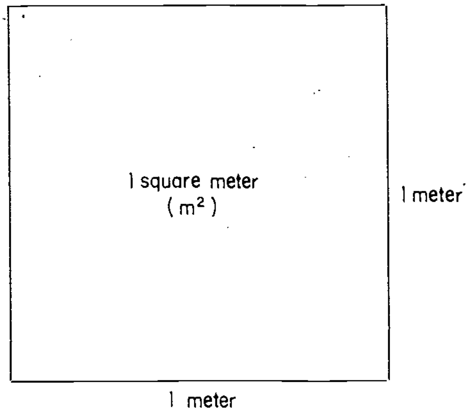
The exercises in checkup set 1 can be used to test your understanding of the metric units for length and their relationships to one another. The answers are located in the back of the book.

METRIC UNITS CHECKUP SET 1

1. 1 m = ______ cm
2. ______ mm = 1 m
3. 1 m = ______ dm
4. 8000 m = ______ km
5. ______ hm = 400 m
6. 3 km = ______ m
7. 20 dam = ______ m
8. ______ m = 500 cm
9. 84 cm = ______ mm
10. ______ m = 3500 mm
11. 80 cm = ______ m
12. ______ mm = 0.2 m
13. 5.3 dam = ______ hm
14. 3 m = ______ km
15. 0.027 km = ______ dm
16. 3.6 m = ______ mm
17. ______ mm = 0.5 dm
18. ______ km = 50 cm
19. 0.03 km = ______ dam
20. ______ hm = 47 cm

Area

The area of a region refers to the number of units it takes to cover the region completely. The basic SI unit of area is the *square meter*. A square region one meter long and one meter wide has an area of one square meter. For help in thinking metric, try to visualize the top of a large card table. The area of the table top is a little less than one square meter. But careful! The area of the top of a small card table (30 inches by 30 inches) is only about one-half of a square meter. Try to find some other familiar object that will provide a better model for a square meter. The SI symbol for a square meter is m².

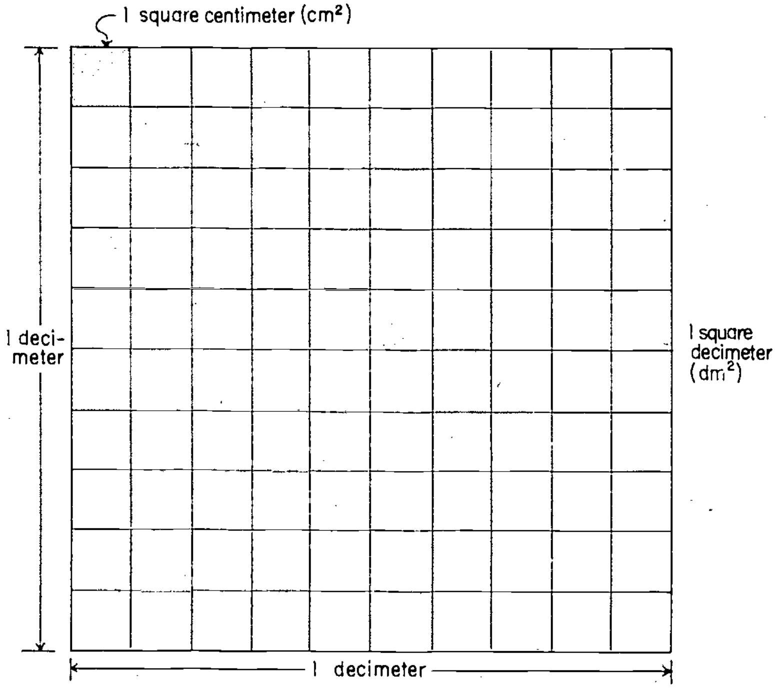


Reporting all areas in square meters is not convenient, since it would result in using very large numbers for large areas and some difficult decimal numerals for small areas. Therefore, for practical purposes, it is convenient to introduce other units of area.

A square region one decimeter long and one decimeter wide has an area of one *square decimeter* (dm²). The bottom of a half-gallon paper milk carton is approximately one square decimeter. A square meter contains one hundred square decimeters ($1\ m^2 = 100\ dm^2$).

A square region one centimeter long and one centimeter wide has an area of one *square centimeter* (cm²). The fingernail of the little finger has an area approximately one square centimeter. A square decimeter contains one hundred square centimeters ($1\ dm^2 = 100\ cm^2$).

A square region one millimeter long and one millimeter wide has an area of one *square millimeter* (mm²). The end of the wire in a jumbo paper clip is approximately one square millimeter. A square centimeter contains one hundred square millimeters ($1\ cm^2 = 100\ mm^2$).



It should be noticed from the preceding discussion that the units of area are related to each other by multiples of one hundred; that is,

$$1\ m^2 = 100\ dm^2 = 10\ 000\ cm^2 = 1\ 000\ 000\ mm^2.$$

The following units of area are all larger than a square meter:

square dekameter (dam^2) ($1\ dam^2 = 100\ m^2$)	a square region with each side 1 dekameter long
square hectometer (hm^2) ($1\ hm^2 = 10\ 000\ m^2$)	a square region with each side 1 hectometer long
square kilometer (km^2) ($1\ km^2 = 1\ 000\ 000\ m^2$)	a square region with each side 1 kilometer long

A commonly used metric unit of land measure is the square hectometer, also called a *hectare*. A hectare is about the size of two football fields side by side, or about 2.5 times as large as an acre. With the adoption of the metric system, land will be bought and sold by the hectare or a portion of a hectare. However, property deeds will not be changed to metric units until a property is sold; thus the changeover in this regard will be a very slow process.

For practical measurements the three units of area that are most often used are the cm^2, m^2, and hectare. The km^2 may also be

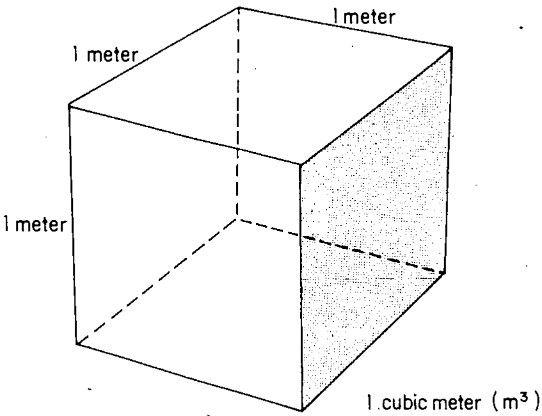
used for reporting large areas of land, such as the area of a state or a continent, or for large surfaces of water, such as the Atlantic Ocean. A km² is how many times as large as a hectare?

METRIC UNIT CHECKUP SET 2

1. 1 m^2 = ______cm^2
2. ______mm^2 = 1 cm^2
3. 1 hectare = ______hm^2
4. 1 hm^2 = ______m^2
5. 1 m^2 = ______mm^2
6. ______ hectare(s) = 8 hm^2
7. ______cm^2 = 3 dm^2
8. 1 hectare = ______m^2
9. 80 m^2 = ______cm^2
10. ______mm^2 = 1.5 cm^2
11. 6 m^2 = ______dm^2
12. ______hectare(s) = 1 km^2
13. 300 cm^2 = ______m^2
14. 2000 m^2 = ______hectare(s)
15. ______cm^2 = 50 mm^2
16. 0.4 m^2 = ______cm^2

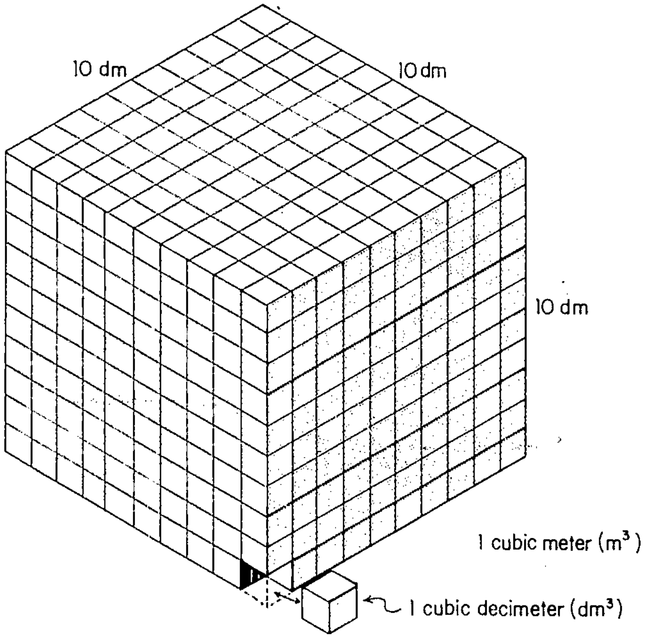
Volume (Capacity)

The volume of an object refers to the amount of space the object occupies or encloses. One of the standard units of volume in the metric system is the cubic *meter*. A cube one meter long, one meter wide, and one meter high has a volume of one cubic meter. The packing case for an average-sized home washing machine has a volume of approximately one cubic meter.



The SI symbol for cubic meter is m^3. To help in remembering the correct use of metric symbols, keep in mind that volume is a physical quantity of three-dimensional objects.

For measuring volumes of less than a cubic meter, smaller units of volume are used. A cube one decimeter on a side has a volume of one cubic decimeter (dm^3). A quart milk container has a volume



slightly less than 1 dm^3. If a cubic meter were to be filled with cubic decimeters, how many would be needed?

Each layer in the model of the cubic meter contains 10 rows with 10 dm^3 in each row, or 100 dm^3. To fill the entire cubic meter requires 10 layers with 100 dm^3 in each layer, or a total of 1000 dm^3; thus, 1 m^3 = 1000 dm^3.

A cube one centimeter on a side has a volume of one cubic centimeter (cm^3). A sugar cube is slightly larger than a cubic centimeter. There are 1000 cubic centimeters in one cubic decimeter; so 1 dm^3 = 1000 cm^3.

A cube one millimeter on a side has a volume of one cubic millimeter (mm^3). A cubic millimeter is a very small unit of volume: one grain of salt is approximately one cubic millimeter. There are 1000 cubic millimeters in one cubic centimeter; 1 cm^3 = 1000 mm^3.

From the preceding discussion it should be clear that units of volume are related to each other by multiples of one thousand. For example, 1 m^3 = 1000 dm^3 = 1 000 000 cm^3. How many mm^3 are in 1 m^3?

Units greater than a cubic meter are used to measure very large volumes, but these units are rarely used for practical situations. A cube one dekameter on a side has a volume of one cubic dekameter (dam^3); so 1 dam^3 = 1000 m^3. An average two-story house would

fit inside a cubic dekameter with a great deal of room to spare. Two larger units of volume are the cubic hectometer (hm^3) and the cubic kilometer (km^3); $1\ hm^3 = 1000\ dam^3$ and $1\ km^3 = 1000\ hm^3$. It may be difficult to imagine these large units, but if a hole is dug in the shape of a rectangular box 1 mile long, 1 mile wide, and 650 feet deep, approximately 1 cubic kilometer of earth would be removed.

The term *volume* is used regardless of whether the space is occupied by a vacuum, a gas, a liquid, or a solid. Capacity is the term used for the space enclosed. When metric units for capacity are used, there is no need to distinguish between dry and liquid measure, which must be done with English customary units.

It is recognized that the cubic meter (approximately 250 gallons) is too large to serve as the unit of capacity for most common measures and the cubic centimeter (approximately 20 drops) is too small. Thus, for practical usage, the cubic decimeter (a little larger than a quart) is the most common unit of capacity measure. Another name for a cubic decimeter is the *liter* (also spelled *litre*). An italic *l* is used here as the symbol for liter because the lowercase l, the international symbol, is in general not distinguishable from the numeral one. Remember that dm^3 and *l* are symbols for the same unit; hence $1\ dm^3 = 1\ l$.

A cubic decimeter contains 1000 cubic centimeters. Therefore, a cubic centimeter is one-thousandth of a liter, or one cubic centimeter is equal to one milliliter ($1\ cm^3 = 1\ ml$).

A cubic meter contains 1000 cubic decimeters. Therefore, a cubic meter is equal to one kiloliter ($1\ m^3 = 1\ kl$).

The prefixes *hecto-* and *deka-* can be used to represent a capacity greater than a liter; *deci-* and *centi-* can be used to represent a capacity less than a liter.

For common usage, however, *kiloliter*, *liter*, and *milliliter* are sufficient and are the only units of capacity that need to be emphasized. These three units and the alternate ways of naming them are summarized in table 3.

TABLE 3
UNITS OF VOLUME (CAPACITY)

1 cubic meter = 1 kiloliter ‖ ‖ 1000 cubic decimeters = 1000 liters	$1\ m^3 = 1\ kl$ ‖ ‖ $1000\ dm^3 = 1000\ l$
1 cubic decimeter = 1 liter ‖ ‖ 1000 cubic centimeters = 1000 milliliters	$1\ dm^3 = 1\ l$ ‖ ‖ $1000\ cm^3 = 1000\ ml$
1 cubic centimeter = 1 milliliter	$1\ cm^3 = 1\ ml$

METRIC UNIT CHECKUP SET 3

1. 1 liter = ______ dm^3	11. 572 m^3 = ______ kl
2. ______ cm^3 = 400 ml	12. ______ m^3 = 400 l
3. ______ dm^3 = 3 m^3	13. 700 cm^3 = ______ dm^3
4. 1 kl = ______ m^3	14. 5800 dm^3 = ______ kl
5. 4 dm^3 = ______ ml	15. 0.5 l = ______ cm^3
6. 15 l = ______ ml	16. 8.3 dm^3 = ______ ml
7. ______ = 5000 cm^3	17. 18 ml = ______ dm^3
8. 1 m^3 = ______ ml	18. 0.05 m^3 = ______ ml
9. 6000 cm^3 = ______ ml	19. 30 cm^3 = ______ l
10. 480 dm^3 = ______ l	20. ______ m^3 = 247 dm^3

Mass (Weight)

The *mass* of an object refers to a measure of the amount of matter contained in the object. Since the amount of matter in an object remains constant, the mass of an object, regardless of where it is measured, remains constant.

The term *weight* has been used in many different ways, resulting in confusion. In our everyday lives it is used to mean mass. In this usage weight is measured in kilograms or grams. In physics and technology, however, it is used as a force related to gravity. In this usage, the weight of an object stationary on the earth was defined as being equal to the force of gravity on the object and was measured in newtons. This use of the term *weight* is now falling into disfavor.

In physics and technological study it is necessary to make a careful study of the concept of force. For now, it is sufficient simply to remember that force is measured in newtons and *not* in kilograms. Because weight was in the past often used as a force, an example of that usage may be of interest. Weight as a force of a body can be considered as the force of reaction that the body exerts on all forces that are in contact with it. An astronaut is said to be "weightless," that is, his weight is zero, when he is in space or during his long voyage in Skylab. This obviously does not mean that his *mass* is zero. It means only that there are no forces acting on him against which to react. He thus feels "weightless" even though he is not "massless."

Because of this confusion, the term *weight* will be avoided more and more in science and technology. In this book the use of the term *weight* will be synonymous with *mass*. If *force of gravity* is implied, it will be so stated and the term *weight* will not be used in this way. Thus weight will be expressed in kilograms or grams, and force of gravity will be expressed in newtons.

One method of obtaining a measure of the mass of an object is to compare it with standard mass units by means of a balance scale. The standard metric units of mass are related to the metric units for length and capacity.

The base SI unit for mass is the *kilogram*. A kilogram has approximately the mass of one liter (one dm^3) of pure water at 4 degrees Celsius (39.2 degrees Fahrenheit), the temperature at which water has the greatest density. The kilogram is the only base metric unit that contains a prefix. A kilogram mass is approximately equal to 2.2 pounds.

Some of the other metric units for mass are shown in table 4.

TABLE 4
UNITS OF MASS

Unit Name	SI Symbol	Value in Grams
kilogram	kg	1000 g
hectogram	hg	100 g
dekagram	dag	10 g
gram	g	1 g
decigram	dg	0.1 g
centigram	cg	0.01 g
milligram	mg	0.001 g

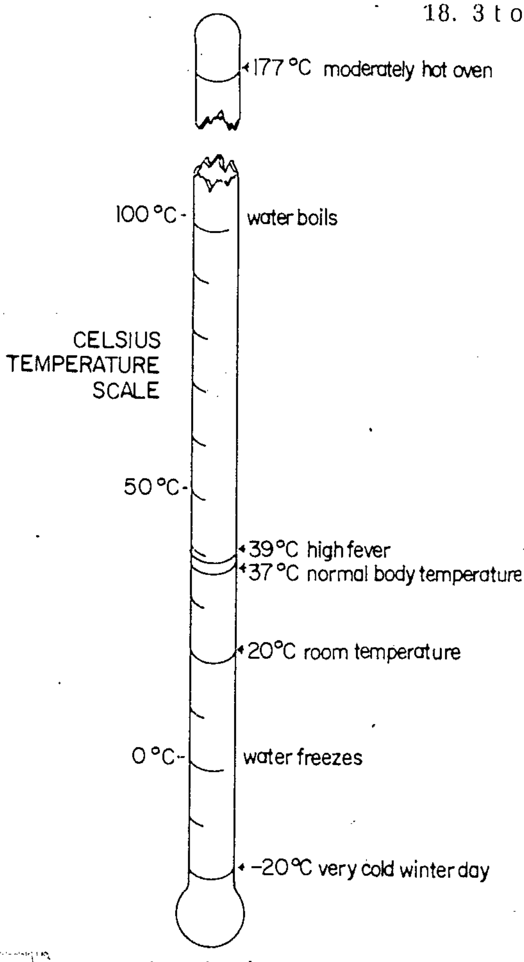
The italicized units are the units that are commonly used and therefore are the only ones to be emphasized. Kilograms are used to measure the mass (weight) of a person, a bag of potatoes, a large packing crate, or other large objects. Grams are used to measure the mass (weight) of a package of nuts, a letter, a coin, a box of cereal, and the like. One cm^3 of cold water has a mass of one gram, a nickel has a mass of approximately 5 grams, and a size-D flashlight battery has a mass of approximately 100 grams. Milligrams are used for measuring the mass of chemicals in experimental work and in medicines. An average-sized postage stamp has a mass of approximately 20 milligrams.

One other common unit, used for measuring the mass of very large objects like the cargo of a ship or the amount of concrete in a building, is the *metric ton* (t). A metric ton is equal to 1000 kilograms; therefore, 1 t = 1000 kg. The spelling *tonne* is also used for metric ton. A cubic meter of cold water has a mass of one metric ton. A mass of 1 t has a weight of approximately 2200 pounds.

METRIC UNIT CHECKUP SET 4

1. 2 kg = ______ g
2. ______ g = 4000 mg
3. ______ kg = 1 t
4. 47 g = ______ mg
5. 6600 g = ______ kg
6. 6500 kg = ______ t
7. 4.8 kg = ______ g
8. 700 mg = ______ g
9. ______ kg = 50 000 g
10. 18 000 mg = ______ kg

11. 15 cm³ of water has a mass of ______ g
12. 5*l* of water has a mass of ______ kg
13. ______ kg of water has a volume of 7 dm³
14. 18m³ of water has a mass of ______ t
15. 27 m*l* of water has a mass of ______ g
16. ______ g of water has volume of 1.6 dm³
17. 8 kg of water has a volume of ______ m*l*
18. 3 t of water has a volume of ______ k*l*



Temperature

The kelvin (K) is the base unit for temperature. The kelvin scale has the point for absolute zero at 0 K, the freezing point for water at 273 K, and the boiling point for water at 373 K. The kelvin scale is used in most scientific work, but for most practical situations the Celsius scale (formerly called "centigrade") will be used. On the Celsius scale the freezing point for water is zero degrees (0°C) and the boiling point for water is one hundred degrees (100°C). A change of one degree on the Celsius scale is exactly the same as a change of one degree on the kelvin scale, and so the degree Celsius (°C) is an acceptable alternative for the base SI unit for temperature.

To become familiar with the Celsius scale for temperature measurements, it is helpful to try to remember several reference points in the new temperature measures. The scale shown will help identify several familiar references that may serve as memory aids.

Time

Units of time in the metric system are the same as our customary units. The base SI unit of time is the second (s).

The exercises in checkup set 5 can be used to test or review all the units introduced thus far.

METRIC UNIT CHECKUP SET 5

1. 170 dm = ______ m
2. 237 cm = ______ m
3. 418 cm = ______ mm
4. 37 000 mg = ______ g
5. 4300 mm = ______ dm
6. 37 g = ______ mg
7. 12 m = ______ cm
8. 500 000 *l* = ______ k*l*
9. 370 dm = ______ cm
10. 17 kg = ______ g
11. 487 000 cm = ______ km
12. 900 *l* = ______ m*l*
13. 7 kg = ______ mg
14. 19 km = ______ cm
15. 72 800 m*l* = ______ *l*
16. 3 k*l* = ______ *l*
17. 238 cm^3 = ______ m
18. 17 m^3 = ______ cm^3
19. 16 000 dm^3 = ______ kg of water
20. 28 liters = ______ cm^3
21. 1 hectare = ______ m^2
22. 8000 dm^3 = ______ liters
23. 1500 m^3 of water weighs ______ t
24. 27 000 cm^3 = ______ dm^3
25. 16 m^2 = ______ cm^2
26. A typical speed limit for city driving is
    a. 20 km/h
    b. 6.5 km/h
    c. 45 km/h
    d. 75 km/h
27. The average height of a door frame in a house is
    a. 3.5 m
    b. 1800 dm
    c. 700 cm
    d. 2200 mm
28. The average mass of a new born baby is
    a. 6.5 kg
    b. 40 000 mg
    c. 300 g
    d. 0.003 t
29. A pleasant temperature for a picnic is
    a. 85 °C
    b. 50 °C
    c. 25 °C
    d. 15 °C
30. A typical household scrubbing bucket will hold about
    a. 45 dm^3
    b. 8000 cm^3
    c. 30 *l*
    d. 6 k*l*

Other SI Units

Table 5 shows the seven base units of the International System of Units (SI). (The units for electric current and amount of substance are not discussed in this booklet.)

Prefixes other than those already introduced are used to represent very large or very small units. The entire list of prefixes is

TABLE 5
THE SEVEN BASE UNITS OF THE SI

Unit Name		Symbol
meter	(length)	m
kilogram	(mass)	kg
second	(time)	s
ampere	(electric current)	A
kelvin	(thermodynamic temperature)	K
candela	(luminous intensity)	cd
mole	(amount of substance)	mol

displayed in table 6. The prefixes represent decimal multiples and submultiples of all SI units.

TABLE 6
PREFIXES FOR SI UNITS

Prefix Name	Symbol	Factor by Which the Unit Is Multiplied
exa	E	10^{18} (quintillion)
peta	P	10^{15} (quadrillion)
tera	T	10^{12} (trillion)
giga	G	10^{9} (billion)
mega	M	10^{6} (million)
kilo	k	10^{3} (thousand)
hecto	h	10^{2} (hundred)
deka	da	10 (ten)
deci	d	10^{-1} (tenth)
centi	c	10^{-2} (hundredth)
milli	m	10^{-3} (thousandth)
micro	u	10^{-6} (millionth)
nano	n	10^{-9} (billionth)
pico	p	10^{-12} (trillionth)
femto	f	10^{-15} (quadrillionth)
atto	a	10^{-18} (quintillionth)

In addition to using the SI units, metric nations use a number of practical units for commerce and trade. A few of the most important of these practical units are shown in table 7. Many of these are already familiar.

TABLE 7
PRACTICAL METRIC UNITS

Name of Unit	Symbol
hectare (area)	ha
liter (capacity)	*l*
minute (time)	min
hour (time)	h
day (time)	d
metric ton (mass)	t
degree Celsius (temperature)	°C
kilometer per hour (speed)	km/h
revolution per minute (rotational speed)	r/min
kilowatt hour (energy)	kW·h

Many derived metric units are formed by mathematical multiplication and division of base SI units. The derived units are important for measurements in engineering and the sciences. However, since the topics they cover are generally not considered part of the elementary or junior high school program, the derived units are not included in this book.

An understanding of the information presented in this chapter is sufficient to use the metric system effectively in practical situations.

3

Teaching the Metric System

ONE OF THE objectives of the elementary and junior high school programs is to teach the concepts of measurement. Teaching the metric units of measurement should be a means to this end, with the major emphasis on the understanding of measurement. Teaching metric concepts by rote or before children are ready to comprehend the ideas will lead only to superficial learning at best and more likely will cause unnecessary confusion. Do not teach the metric system just to "get on the bandwagon"—the metric system should be presented as part of a well-planned and coordinated program of teaching measurement across all subject areas as well as within the K–12 mathematics program.

Some Pedagogical Guidelines

The best way to learn metric measurement is to use the system. This requires many varied hands-on activities that will familiarize children with metric units of measurement and the proper uses of measuring instruments. One important function of these activities is to show a need for new units before they are introduced. Of course, the activites should be interesting to children and be designed to require both physical and mental involvement of children.

The metric system should be taught as the principal system of measurement with emphasis on the relationship between the units

within the system. The metric system of measurement should be taught first, for it will be the predominant measurement system for students in their daily activities when they are adults. It is suggested that children not be required to convert from customary units to metric units or from metric units to customary units. These types of exercises are usually unproductive. An exception might be to use conversions between systems as sample exercises involving ratios and proportions or as problem-solving exercises.

If a need is felt for conversions between systems of units in the courses that are taught, it is suggested that a set of metric converters be obtained for the children to use rather than have them do all the conversions by hand. The type of converter chosen will depend on the degree of precision desired. Electronic hand-held calculators that do conversions automatically are available. They are very precise, but they are also very expensive. Many other converters of the slide-rule type are available at very low cost—or at no cost as a promotional giveaway—from some of the industrial and educational supply companies and from publishing companies.

It may be necessary for a short time to compare metric units to familiar customary units to help children adjust to the metric system. This will be especially true for upper elementary and junior high school students who have already studied the customary units of measurement. Identifying a familiar object with each of the three basic metric units should enable a student (or adult) to make a smooth transition to the use of the metric system. A set of useful comparisons for the transition period are—

- a meter—a little more than a yard (about 10 percent more)
- a liter—a little more than a quart (about 5 percent more)
- a kilogram—a little more than two pounds (about 10 percent more)

Even though it is unlikely that elementary and junior high school teachers will be able to ignore completely the customary units of measurement or forget completely what they already know about these units, the emphasis in teaching metric measurement should be on THINK METRIC and DO METRIC. An excellent strategy for achieving these objectives is to make extensive use of estimation. Have the children estimate measurements in metric units (THINK METRIC) and then check their estimates by using appropriate measuring instruments calibrated in metric units (DO METRIC). If these types of activities are done on a regular basis as part of the usual drill-and-practice activities, children will become proficient in using the metric system.

Emphasize only those prefixes that are commonly used. The kilometer, meter, centimeter, and millimeter are the most practical units for measuring length. Since the prefix *deci-* is used when defining the liter as a cubic decimeter and the decimeter is a convenient unit of length for some problems, the prefix *deci-* should be introduced and used in problem situations, but it does not deserve the same emphasis as the prefixes *kilo-*, *centi-*, and *milli-*. The kiloliter, liter, and milliliter are the most common measures for volume (capacity). The milligram, gram, kilogram, and metric ton are used in most practical situations for measuring mass. Children should be familiar with the meanings of *hecto-* and *deka-*, but it is a waste of time and effort on the part of both students and teachers to do many problems involving these prefixes. In general, using prefixes that are powers of 1000 (with the exception of *centi-*) is recommended.

The United States monetary system serves as an excellent model for introducing metric prefixes. With the dollar as a base unit, *deci-* corresponds to *dime* (one-tenth of a dollar), *centi-* corresponds to *cent* (one-hundredth of a dollar), and *milli-* corresponds to *mill* (one-thousandth of a dollar). The prefixes for units greater than the base unit are not as clearly related to multiples of a dollar, but *deka-* can be related to ten dollars, *hecto-* to one hundred dollars, and *kilo-* to one thousand dollars.

Measurement should be taught as a practical skill. Therefore, it is important that children have the opportunity to apply what they learn to real-world situations. All teachers should provide an abundance of relevant examples and laboratory experiences to show where and how the metric system is now used and will be used. Some examples are using metric measurement in cooking and baking; identifying the amount of foodstuff in a can or box in terms of metric units of mass or capacity; using metric measures in world trade (check the business section of a daily newspaper); using metric measures in agriculture, industry, and commerce (several American products are already entirely metric); and using metric measures in athletic events. These types of examples and laboratory activities are rarely found in textbooks. They must be created by classroom teachers in all subject areas.

The heavy emphasis on computation with fractions that now exists in K–6 mathematics programs is due in large part to the need for these skills to cope with the units of measure in our customary system. With the teaching of the metric system as the principal system of measurement, the emphasis will be on decimal numerals. Since the computational skills needed to work with metric units are no different than those needed to work with other decimal

numerals, including work with monetary units, this provides a greater unity to the work with decimals. In addition, the amount of time devoted to drill on computation with fractions can be decreased substantially, since high-level mastery of these skills is less important. The time that is gained can be used for additional work with decimal numerals or other aspects of mathematics. Of course, this does not mean that all work with fractions should be deleted. Children still need to have an understanding of the meaning of fractions and basic principles of computation with fractions. A basic understanding of fractions is needed to understand decimals. Also, fractions like $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{3}$ and others will continue to be used.

Guidelines for Spelling, Punctuation, and the Use of Symbols

Since the SI units are part of an international system, certain guidelines should be followed so that children will learn the proper use of symbols and punctuation. Some of these guidelines apply for every metric country in the world, and so there is truly an international language of measurement, independent of the native language of any country.

SI symbols are not abbreviations. Therefore a symbol is not followed by a period except at the end of a sentence. SI symbols are truly international and identically the same in every country of the world. The word *meter* is *mètre* in French, *metro* in Spanish, and *vermass* in German, but m is the symbol for meter in every country.

SI symbols are both singular and plural. For example, 15 centimeters is symbolized as 15 cm, *not* 15 cms.

All SI unit names, with the exception of degree Celsius, are lowercase letters. Of course, any unit name would be capitalized when it is used as the first word in a sentence.

All the prefix names for decimal multiples and submultiples of the SI basic units are lowercased. The majority of the symbols for these prefixes are lowercased; the exceptions are E for the prefix *exa-*, P for the prefix *peta-*, T for the prefix *tera-*, G for the prefix *giga-*, and M for the prefix *mega-*. It is important that the proper capitalization for each symbol be used; otherwise, significant errors in interpretation may result. For example, the symbol mm represents one millimeter (0.001 meter), but the symbol Mm represents one megameter (1 000 000 meters).

Symbols for many of the derived SI units are capital letters—for example, N for newton (unit of force), J for joule (unit of work or energy), W for watt (unit of power), C for coulomb (unit of quan-

tity of electricity), and V for volt (unit of electric potential or electromotive force). Not all the derived SI units are listed in this book, since they are not commonly introduced in the elementary and junior high school program.

The prefixes *deci-*, *centi-*, *deka-*, and so on, are used only with a unit, never by themselves. For example, the expression "a mass of one kilo" is improper; the expression should be "a mass of one kilogram."

In writing a numeral with a symbol, leave a half-space or a full space between the two. For example, twelve milligrams should be symbolized as 12 mg. The use of the space helps to distinguish this type of symbol from 12mg, which is used in mathematics to represent the product 12 times *m* times g, where m and g are variables. Of course, the context in which the symbols are used should also help to clarify the difference between symbols like 12 mg and 12*mg*.

Symbols have been used improperly in some of the currently available films, filmstrips, textbooks, and workbook materials, and on some labels, tools, and the like. The teacher should be able to recognize such errors and point them out to students.

When writing a decimal numeral for a number less than one, include a lead zero to the left of the decimal point to "set it off." For example, twenty-three hundredths should be written 0.23, five thousandths should be written 0.005, and so on.

When writing numerals for very large or very small numbers, separate the digits into groups of three to aid in reading the numeral: use a space or a half-space, not commas, to separate the groups. For example, three million two hundred twelve thousand twenty-four meters is written 3 212 024 m. Commas are no longer used to separate groups of three digits because they are used as decimal markers in foreign countries. Digits to the right of the decimal point are also grouped in threes and separated by a space. For example, 0.324 04 cm and 87.032 547 g.

4
Instructional Materials and Activities

TO TEACH the metric system, some basic measuring instruments calibrated in metric units are needed, and recommended materials for teaching the concepts of length, volume, and mass can be found

in the list that follows. A limited supply budget should not prevent the teaching of the metric system—most of the essential equipment can be purchased at low cost, materials can be shared by several teachers, and many of the pieces of equipment can be constructed by teachers or students at very little or no cost. Suggestions for constructing some of the homemade equipment are included.

Some suggestions for class activities for teaching measurement are also presented in this chapter. Since many of the activities are described in general terms, teachers must modify the ideas to fit their particular needs. Grade level, students' previous experience with metric units, the availability of equipment, and the abilities of the students are some of the variables that should be considered when adapting an activity to a specific classroom lesson.

These activities should not be considered the only things that can be done. They are presented as a *sample* of things to do, and it is hoped that these ideas will serve as a basis for the teacher to use in developing additional classroom activities.

Linear and Area Measurement

Recommended materials

The following materials are recommended for teaching the concepts of linear and area measurement. Those items marked with an asterisk are considered essential.

*Unmarked dowels of various lengths (1 cm to 1 m)
*Meterstick calibrated in cm and mm
*Tape measures (1 m or 1.5 m)
*Metric rulers (30 cm)
*Metric graph paper (cm²)
Clear plastic centimeter grids
Metric height-measuring standard
Metric shoe size–measuring standard
Trundle wheel
Calipers
Metric depth gauge
Centimeter rods (wooden, plastic, or cardboard)
Metric micrometer

Homemade materials

Students can construct their own meterstick by gluing a cutout pattern of the meter onto thin lath or heavy cardboard. The pattern can be drawn by the teacher on a ditto master (four sections, 25 cm each, or five sections, 20 cm each, will fit easily on a standard-sized master). If a printed reproducible master copy of a pattern is available, it can be reproduced by ditto, mimeograph, or—if possible—offset printing, which will produce the most accurate copy.

Tape measures can be constructed in a similar manner. The dis-

carded end pieces of cut-to-order window shades provide a no-cost source of durable, no-stretch plastic for the tape measures. A store that sells window shades will no doubt provide the scrap ends for the asking.

If a cutout pattern is not available, students can mark metric unit divisions on a lath, a strip of plastic, or a strip of cardboard by using a calibrated meterstick as a model.

A piece of rope or heavy twine can serve as a metric tape. Knots can be tied at every meter, every five meters, or every ten meters, depending on the intended use, and painted a bright color.

Activities for Length and Area

Primary grades

Compare the lengths or heights of several objects and identify the longest or shortest. Arrange a set of three or more objects in order from shortest to tallest. Compare the lengths of two fixed objects by using a third object (a stick, a piece of string, or some similar nonstandard unit).

Find an object that is the same length (or almost the same length) as a given length (nonstandard unit).

Find the length of an object using another object as a unit of length. For example, how many sticks long is the desk top? A large number of sticks, paper strips, centimeter rods, or some other model of the unit should be available so that they can be placed end to end on the object to introduce the idea of measurement by iteration.

Using nonstandard units such as a hand span, a pace, a long stick, or a piece of yarn, the children should first estimate the length of an object and then use their unit to measure the length to check their estimate.

Use several different nonstandard units to measure the length of an object. A discussion of the varied answers that result should lead children to the realization of a need for a standard unit.

Introduce standard units by letting children choose their own basic standard unit for the class and name the unit themselves. Appropriate follow-up measurement activities can then lead children to suggest either subdividing the basic unit into smaller standard units or creating larger multiples of the basic unit.

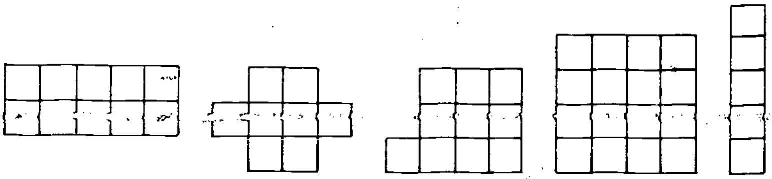
Introduce the meter first and then the centimeter as the first metric units. Provide activities in which the children will have to find lengths that fall between units, for example, between 2 m and 3 m or between 33 cm and 34 cm. This should lead to the idea of giving answers to the nearest unit.

Establish the relationship of 1 m = 100 cm by measuring the length of several objects with both units. Begin with objects that are one or two meters long.

Have available metersticks and rulers marked off with the centimeter as the smallest unit. Estimate and then measure the length of a common object to the nearest meter or nearest centimeter; repeat with a great variety of common objects.

Have one pupil write the length of a "mystery object" on the chalkboard. Other pupils should then use their measuring instruments to measure objects in the room to try to identify the object or find another object of the same length.

Have children count the number of square regions in figures like these:



This is a readiness activity for the concept of area.

Intermediate grades

A worksheet similar to the one shown in figure 1 is fun for the students and can lead to a discussion of how metric units are used in clothing sizes, dress patterns, and the like.

Establish the relationships between centimeter, decimeter, and meter by measuring the same object with all three units. A worksheet similar to the one in figure 2 can be used to help pupils see the relationships between the units.

Have children make their own meterstick or tape measure and take it home to measure various lengths and areas in their home and neighborhood. A note to the parents explaining the metric units the children are to use for this activity will help acquaint the parents with the metric system.

Select the most appropriate unit for measuring the length or width of an object. For example, say, "The most suitable unit for measuring the width of your mathematics book is *(a)* centimeter, *(b)* decimeter, *(c)* meter, or *(d)* kilometer."

Introduce the prefix *milli-* by establishing a need for a unit smaller than a centimeter. Have children attempt to measure very small objects with the available units (meter, decimeter, and centimeter). Follow-up activities should include using a ruler marked in millimeters.

Directions: Find the measurement to the nearest centimeter for each part of your body listed below. (Use a tape measure or a piece of string and a meterstick.)

1. The distance around your thumb. _______ cm
2. The distance around your neck. _______ cm
3. The distance around your wrist. _______ cm
4. The width of your hand with fingers and thumb together. _______ cm
5. The distance around your head at the top of your eyebrows. _______ cm
6. The distance from the fingertip of one hand to the fingertip of the other hand with arms outstretched. _______ cm
7. Your height. _______ cm
8. The distance around your waist. _______ cm
9. The distance from heel to toe. _______ cm
10. The distance from your elbow to your longest fingertip. _______ cm
11. The distance from knee to ankle. _______ cm
12. What relationships (if any) do you see between the measurements you found? (*Hint:* compare #2 and #3, #6 and #7, #10 and #11.
13. How could you find your metric hat size from #5?
14. How could you find your metric shoe size? Glove size?

Fig. 1

Introduce the prefixes *deka-*, *hecto-*, and *kilo-* by showing a need for units of measure larger than a meter. This can be accomplished best by measuring long distances out of doors. Also, use these measurement activities to show the relationships between the dekameter, hectometer, and kilometer.

Directions: Measure the length of each object three times using a different unit each time.

	centimeters	decimeters	meters
Length of the bookshelf	_______	_______	_______
Length of the chalkboard	_______	_______	_______
Height of the doorframe	_______	_______	_______
Width of the bulletin board	_______	_______	_______
Length of the worktable	_______	_______	_______

Do you see a pattern between the lengths of each object you found using the three different units?

Can you find the length of an object in decimeters and centimeters by using the length in meters?

Can you find the length of an object in decimeters and meters by using the length in centimeters?

Fig. 2

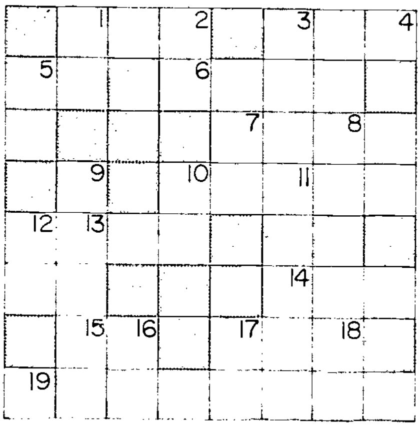
TABLE 8
PLACE VALUE CHART

thousands	hundreds	tens	units	tenths	hundredths	thousandths
thousand dollars	hundred dollars	ten dollars	dollar	dime	cent	mill
kilo-	hecto-	deka-	basic unit	deci-	centi-	milli-

Use monetary values as a model for introducing decimal notation for metric units. The chart in table 8 will help illustrate the idea.

Have the children draw a segment of a given length by estimation. If they work at the chalkboard, the specified lengths can vary from millimeters to meters. Paper-and-pencil work is usually limited to millimeters and centimeters.

Have children construct crossword or crossnumber puzzles for other members of the class to work. The teacher should probably construct one puzzle as an example. The types of puzzles the children construct are a good indicator of how well they understand the relationships between the units. One example of a metric crossword puzzle follows.



ACROSS

1. 10 m = 1 ______
3. 10 dm^3 = 1______
5. 1 ______ = 0.1 km
6. The mass of 1 cm^3 of water is one ______
7. The prefix that means 10 times is ______
9. The symbol for the prefix that means 100 times is ______
10. The prefix that means 0.001 times is ______
13. 100 dm = 1______
14. The mass of 1 m^3 of water is one ______
15. 1000______^{3} = 1 liter
19. One liter of water has a mass of 1 ______

DOWN

1. 1 m = 10 ______
2. 1 g = 1000 ______
4. A symbol for 1 dm^3 is ______
5. The symbol for hectare is ______
8. 1000 dm^3 = 1 ______
10. 0.01 dm = 1 ______
11. One ______ of water has a mass of 1 kg

12. 1 ______ = 1000 m

13. The prefix that means 0.1 times is ______

15. Another name for 1 cm^3 is ______

17. 0.001 g = 1 ______

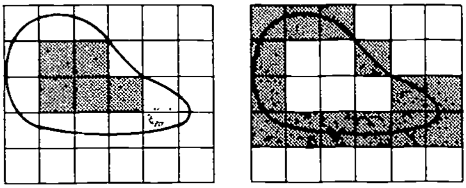
18. The symbol for the prefix deka is ______

Use a "metric unit line" to convert from one metric unit to another. To change from one unit to another, move the decimal point the same number of places and in the same direction that you move on the "line" from the given unit to the new unit.

km	hm	dam	m	dm	cm	mm
			3	5		

Examples: Change 35 dm to hm. From dm to hm you move the decimal point three places to the left; thus, 35 dm = 0.035 hm. To change 35 dm to mm you move two places to the right; thus, 35 dm = 3500 mm.

Use a transparent centimeter grid to estimate the area of an irregularly shaped region. Use this activity to develop the idea of approximating the area of an irregularly shaped region by the sum of the "inner area" and one-half of the "outer area."



"inner area" = 5   "outer area" = 14

Approximate area of the region is $5 + \frac{1}{2}(14)$, or 12 square centimeters.

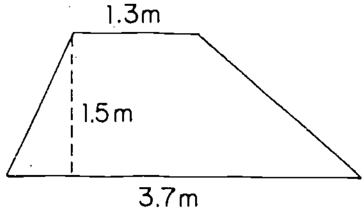
Draw regions with a given area on centimeter graph paper. Stake out regions of large given areas out of doors. Include a region whose area is equal to one hectare.

Junior high school

Use a metric micrometer to measure very small items like the thickness of a piece of paper, the diameter of a thin wire, the thickness of an eggshell, and so on.

Develop area formulas for a rectangle, parallelogram, triangle,

trapezoid, and circle, using metric units in the examples. Provide practice exercises using metric units expressed as decimal numerals in terms of a single unit. This will provide practice in computing with decimal numerals as well as in using the formulas.

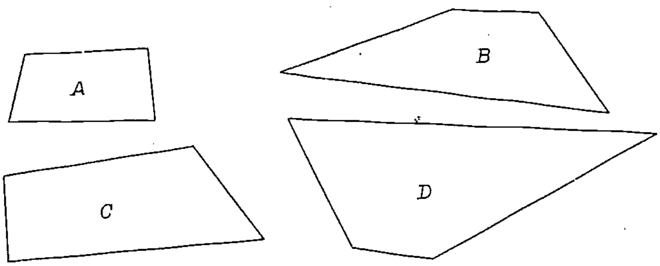


Introduce the idea of the precision of measure and the importance of rounding off to the least precise measure when doing computations with measures.

Introduce prefixes representing multiples greater than 1000 and less than 0.001. Have students find examples of where lengths greater than 999 kilometers and less than 1 millimeter are used. Make a bulletin board with this information.

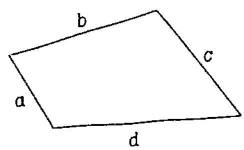
Examples of several worksheets that could be used as enrichment activities follow.

1. Use your centimeter grid to estimate the area of each region.



2. Use this old Egyptian formula to compute the area of each region.

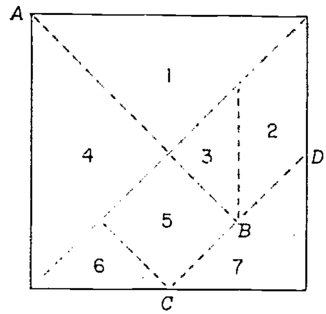
$$\text{Area} = \frac{a + c}{2} \times \frac{b + d}{2}$$



Region	Estimated Area	Computed Area
A		
B		
C		
D		

3. How do your estimates in question 1 compare to the computed values in question 2?
4. For what kinds of regions does the formula seem to work best?

Tangrametrics



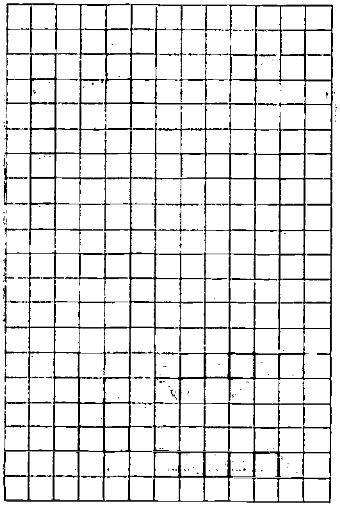
Directions:

Draw the tangram puzzle using a length of 10 cm for each side. Number each piece as shown in the figure. (*Note:* Points *C* and *D* are midpoints.) Use the figure you draw to answer the following questions.

1. Which pieces of the puzzle are congruent?
2. What is the perimeter of the small square (puzzle piece 5)? (Find your answer in two different ways.)
3. What is the area of the small square in cm^2? (Find your answer in two different ways.)
4. Estimate the perimeters and areas of the other puzzle pieces and fill in the following table. When you have filled in all the answers, check with some of the other students in your class and compare your answers.

Number of puzzle piece	Perimeter	Area
1	______ cm	______ cm^2
2	______ cm	______ cm^2
3	______ cm	______ cm^2
4	______ cm	______ cm^2
6	______ cm	______ cm^2
7	______ cm	______ cm^2

5. Find the sum of all the perimeters (include square 5). Is your sum very close to 100 cm? If not, go back over your estimates and try to find which of your answers are "poor" estimates.
6. Find the sum of all the areas. Is your sum very close to 100 cm^2? If not, recheck your estimates.

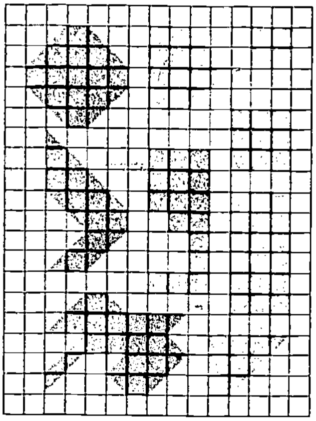


Directions:

1. Estimate the area of each shaded region in cm^2.
2. Count the number of crossing points (where two grid lines cross) on the boundary of each region.
3. Is there a relationship between the area of a region and the number of crossing points on the boundary of the region?
4. Draw some other regions to test your answer to question 3.

Directions:

1. Estimate the area of each region in cm^2.
2. Count the number of crossing points (where two grid lines cross) on the boundary of each region and count the number of crossing points inside each region.
3. Is there a relationship between the area of a region and the number of crossing points on the boundary and the number of crossing points inside the region?
4. Draw some other regions to test your answer to question 3.



Volume (Capacity) Measurement

Recommended materials

The following materials are recommended for use in teaching the concept of volume measurement. Those marked with an asterisk are considered essential.

*Centimeter cubes (wooden or plastic)
*Graduated cylinders (10 m*l* to 1 *l*)
*Cubic decimeter
Graduated beakers (25 m*l* to 1 *l*)
Model of a cubic meter (stick model)
Metric measuring cup (marked in m*l*)
5-m*l* spoons
Overflow displacement bucket
A variety of solid objects of various shapes and sizes
Containers of various shapes (cones, pyramids, cylinders, rectangular prisms, triangular prisms, etc.)

Homemade materials

A calibrated cylinder can be constructed from any glass or plastic container. A tall, thin jar such as an olive jar or a plastic container such as a golf-ball tube will work best. The levels, determined by pouring some predetermined amount of liquid, such as 25 m*l* of water, can be marked with a waterproof marking pen on the side of the container or on a piece of tape affixed to the side of the jar.

Standard capacity measures can be made from empty cans: A two-pound coffee can contains about 2 liters, a juice can (46 oz.) contains about 1500 m*l*, a vegetable can (15 oz.) contains about 500 m*l*, a tomato-soup can (10¾ oz.) contains about 300 m*l*, and a small vegetable can (8½ oz.) contains about 250 m*l*. The cans can

be made more attractive by painting them with a rustproof paint. By experimenting with cans of other sizes, you will be able to make other standard measures.

Plastic measuring cups can be recalibrated to metric milliliter measures by marking the appropriate level and then cutting down the cup to that level. A cup can be cut down to a 200 m*l* measure, a half-cup to 100 m*l*, a fourth-cup to 50 m*l*, and an eighth-cup to 25 m*l*. The plastic can be cut with a sharp knife or a razor blade.

Plastic self-adhesive labels made with a labelmaker of the hand-gun type work very well for marking the capacity of the cans and measuring cups.

Waxed cardboard gallon milk containers can be cut down to form capacity measures of 4 liters, 2 liters, 1 liter, 500 m*l*, and other measures.

Activities for Volume (Capacity)

Primary grades

Compare containers of various sizes. Which one will hold the most? Which one will hold the least? Test the estimates by using water, sand, salt, rice, or similar substances.

Introduce the liter container. Children should find other containers that will hold about one liter, more than one liter, less than one liter.

Build models of three-dimensional figures from centimeter cubes and count the number of cubes in the figure. Determine the number of cubes in a three-dimensional figure by looking at a two-dimensional picture of the solid. These are readiness activities for the concept of volume.

Intermediate grades

Have the children construct a model of a decimeter cube. Give them a pattern or have them figure out a method of their own for making the cube. Use the cube to help introduce the relationships between cm^3 and m*l* and between liter and dm^3.

To help children establish a feeling for the liter and milliliter, have them use a graduate calibrated in milliliters to measure the capacity of many common household items. Use water, sand, salt, rice, or some other similar substance to measure the capacities. Examples of items might include the following:

cup	quart bottle	empty cans
tablespoon	plastic bag	Dixie ice cream cup
thimble	drinking cup	small boxes
pop bottle	jelly jar	small milk carton

Provide a variety of bottles and other containers that vary in shape, size, height, and so on. Have the children estimate which container will hold the largest quantity, which will hold the smallest quantity, and which ones will hold the same amount.

Provide a variety of containers with the same height and the same shape but with different capacities (e.g., all rectangular prisms, all cylinders, all triangular prisms). Have the children use a graduate calibrated in millimeters to determine the capacity of each container. You may want to have the children estimate before they measure. After they have measured the capacities, have them record their findings in a table, on a chart, by a drawing, or by a graph. Ask if they can use their findings to discover some relationship(s) between the capacities and some other measure on the containers (e.g., the area of the base).

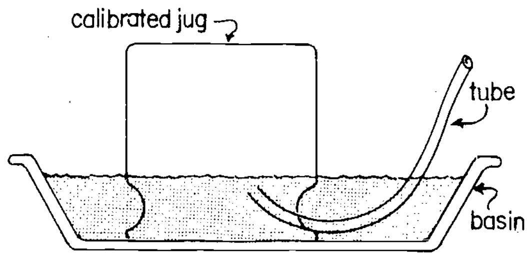
Use two similar three-dimensional objects, such as a ball and a marble, and ask how many marbles would occupy the same amount of space as the ball. Remind the children that they must consider the amount of space that is occupied by air if they think of a container filled with marbles. Use estimation and then computation to check the estimates.

How many gains of rice are needed to fill a one-liter container? Make an estimate. How can you check your estimate?

What is your skin area in cm^2? How does this compare to the skin area of your hand? If you were hollow, what would be your capacity in liters? How many cm^2 of skin do you have for each liter of you? (Have the children lie on a large piece of paper and trace their body outline to help answer the questions.)

Junior high school

Have students estimate their lung capacity in m*l*. Then have students measure their lung capacity by using an apparatus as shown in the diagram. Have a student take a deep breath and exhale by blowing through the tube into the jug. The expelled air will lower the water level inside the jug. The amount of water displaced by the air, measured in m*l*, will provide an approximation of the student's lung capacity. Record the measurements by chart or

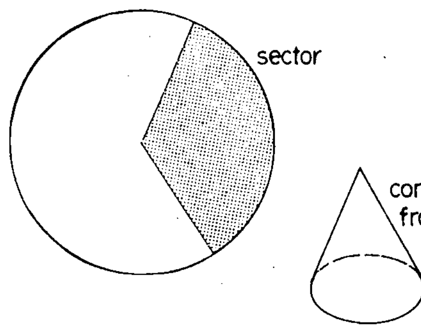


graph. Have students compare lung capacity with height, weight, sex, and other characteristics.

Provide a set of successively larger models of a cube. Have the students measure the length of an edge, surface area, volume, and capacity and record their results on a chart like the one shown. What things stay the same? What things change? Is there a pattern to the changes?

edge	surface area	volume	capacity
1	6	1	1
2	24	8	8
3	54	27	27
4	96	64	64

Use a circle with some predetermined diameter. Cut different sectors from the circle and form cones from the sectors. Measure the capacity of the cones and record the results. What is the relationship between the capacity of the cone and the size of the sector used to form the cone? (The size of a sector is its percentage of the total circle.)



Find the volume of irregularly shaped objects by using the idea of displacement. Find the capacity of very small objects by using an eyedropper (one cm^3 is about twenty drops).

Give the dimensions of a rectangular prism that would have the capacity indicated in the following chart. Give at least two different answers for each part.

3 liters	____	by	____	by	____	dm
20 liters	____	by	____	by	____	dm
4 liters	____	by	____	by	____	cm
500 ml	____	by	____	by	____	cm

Make up some other examples of your own.

Mass (Weight) Measurement

Recommended materials

The following items are recommended for teaching the concept of mass measurement; those items preceded by an asterisk are considered essential.

*Hook-spring scales

*Beam balance

*Platfo·m spring-compression scale

*Set of mass standards (1 g, 5 g, . . . , 500 g, 1 kg)

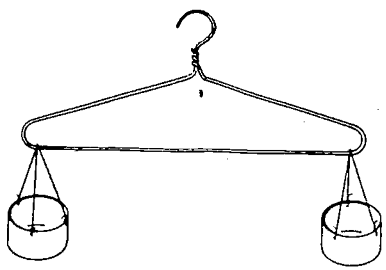
Plastic stacking weights

Personal "bathroom" type of scales

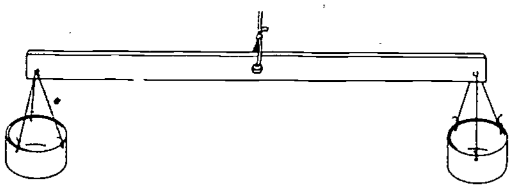
Household type of scales for cooking and baking

Homemade materials

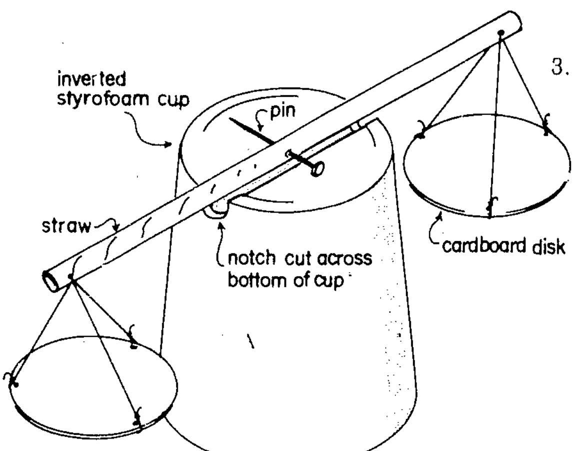
A beam balance can be constructed in one of several ways:



1. *A coat hanger.* Use the plastic tops from spray cans for the pans and make holes in them with a hot wire. Use thin wire or string to attach the pans to the hanger.



2. *A meterstick.* Drill a hole at the point of balance, near the 50-cm mark. Use the same type of pans as for the coat-hanger balance. Drill holes for the pans about 10 cm from the ends.



3. *A straw balance.* Use a plastic straw and a straight pin for the balance arm. Use small cardboard disks and thread for the pans.

Homemade standard weights can be made from clay or pieces of wood and small weights can be cut from heavy wire, but a balance and a set of standard weights are needed to form your own set of

homemade standards. Coins or jumbo paper clips can also be used as reasonable standards for 1-gram, 2-gram, 3-gram, and 5-gram weights.

Activities for Mass (Weight)

Primary grades

Give children a familiar object and ask them to find another object that is heavier or lighter. The children can check their estimates by using a simple beam balance.

Compare objects to determine which is heavier or lighter. Compare the weight of two objects by comparing them to a third object. Order a set of objects from lightest to heaviest.

Weigh each member of the class in kilograms on a personal scale and graph the result.

Have the children bring in small objects, weigh them on a spring scale calibrated in grams, and record their results on a chart or graph.

Determine the weight of a ball of clay by using a beam balance. Reshape the clay into a long "worm" and ask the children if it will weigh the same as before, weigh less, or weigh more. Check the weight of the "worm" on the balance. Reshape the clay into some other distinct type of shape and repeat the process of questioning and checking.

Use a metric recipe to bake some cookies or cupcakes.

Chocometric Cupcakes

Sift together into bowl	100 g	flour
	125 g	sugar
	2 g	salt
	2 g	baking soda
	25 g	cocoa
Add	75 g	butter
	100 m/	milk
Beat 2 minutes		
Add	1	egg
	3 m/	vanilla
Beat 2 more minutes		

Pour the batter into paper-lined muffin pans. Fill cups about half way. Bake in a preheated oven at 177 °C for about 35 minutes. When cool, frost and decorate with M & M's.

Intermediate grades

Weigh a 1 cm^3 wooden block, a 1 cm^3 plastic block, and a 1 cm^3 clay block. Do all cubic centimeters weigh the same?

Find objects in the school or in your home that weigh about

1 gram 5 grams 10 grams 1000 grams.

Build rectangular solids with centimeter cubes. Compute the volume of the solid and determine the amount of water that would be needed to fill the rectangular figure if it were hollow. How much would the water weigh?

Estimate the weight of a large number of very small objects by using the results obtained from a sample.

Find the weight of	*Estimate the weight of*
10 navy beans	10 000 navy beans
15 rice grains	5 000 rice grains
20 paper matches	3 000 paper matches
5 unsharpened pencils	1 500 unsharpened pencils

Give the students equal volumes of rice, beans, and water and have them determine which is the heaviest. Ask them to find the answer in more than one way.

Have the students find the weight of a single pin, thumbtack, pea, or bean. Have them use at least two different methods and discuss the reliability of the results obtained by the different methods. For example, the students might weigh 10 grams of peas and then count the peas. Another method would be to count out 100 peas and then weigh the total number of 100 peas. In each case the weight of a single pea could be found by computation.

Give the students a set of objects and have them weigh the objects and then add the weights. They can check their addition by weighing the entire set at one time. The addition can be made as difficult as you wish by the choice of objects.

Have the students try to find objects of a given weight. For example, find an object at home that weighs 250 grams. Students should bring the objects to class and check their estimates.

Have students find their weight in kilograms and estimate the area of the bottom of their feet in square centimeters. Then they can compute the area load density on the bottom of their feet in kilograms per cm^2 when they are standing on a flat surface.

Students can make their own balance using rubber bands or a spring. They can graduate the balance by using standard weights.

Find labels from cans, boxes, and other food containers that list the weight of the contents in both customary and metric units. Make a chart that shows these comparisons. This is not an activity in conversion; rather, it helps students become more familiar with a common use of metric units.

Junior high school

Give the students a football. Have them first estimate answers for the following questions and then use measuring instruments to determine the actual measurements.

	Estimate	Actual Measurement
1. What is the length of the football?	________	________
2. What is the width of the football?	________	________
3. What is the volume of the football?	________	________
4. What is the weight of the football?	________	________
5. If the football were filled with water, what would be the weight of the football and the water?	________	________

Provide five rocks of different sizes. Have each member of the class estimate the weight of rock 1 and record a guess. Let one student use a scale to weigh the rock and then have all students compute the percent of error between their estimate and the actual weight:

$$\frac{\text{actual weight - estimated weight}}{\text{actual weight}} \times 100 = \underline{\qquad\qquad}\% \text{ of error}$$

Repeat the process with rocks 2, 3, 4, and 5. Then repeat the entire activity, only this time have the students estimate and then find the weight of each rock while it is suspended in water. After both activities, discuss how the percent of error changed with more trials.

Provide eight or more containers of various shapes and sizes. Let students rank the containers according to size by estimation. Then have the students weigh the containers first when empty and then when full of water, thus determining the weight of water each holds when full. From this information they can determine the capacity of each container in m*l* and establish the correct ranking of the containers. This can be used as a game—a student's score will be the absolute value of the differences between his estimated ranks and the actual ranks.

Time and Temperature Measurement

Recommended materials

*Celsius thermometers
Uncalibrated thermometers
A 24-hour clock or a model of such a clock

Activities for Time and Temperature

Activities for telling time will not change with the teaching of the metric system. We shall no doubt continue to use the twelve-hour clock as the principal method for telling time in practical situations.

Children in the upper elementary grades should be able to read and interpret time on a twenty-four-hour clock. Simple routine activities using such a clock, or a model of such a clock, will help children achieve this objective.

The best way to become familiar with the metric units for temperature is by the repeated and constant use of the Celsius scale. Read and record the outdoor temperature and the indoor temperature in degrees Celsius every day. Make a chart or graph of these temperatures for an extended period of time.

Have the children use a Celsius thermometer to measure the temperature of ice water, boiling water, cold pop, and hot tap water, the temperature in different parts of the building, and the like. These temperatures should be recorded on a paper model of a thermometer. A large classroom model or a bulletin board display of the average results would help to fix the ideas of these "new" temperature readings.

Have students calibrate their own thermometer. Provide Celsius thermometers that children can take home with them to measure room temperatures, outdoor temperatures at night, the temperature of the refrigerator, the temperature of ice cream, and so on. This will help to acquaint the parents with the metric system, too.

A Closing Remark

Remember that teaching the metric system does not need to be a crash program. Take time to learn the system yourself. Integrate the system into your teaching in a natural way, using the system yourself whenever possible. Encourage other teachers to use the system and to teach it in their courses when dealing with measurement so that it becomes part of the total program. When you do get involved with the teaching of the system, keep in mind the key words for success: THINK METRIC—DO METRIC.

ANSWERS

Checkup Set 1

1. 100
2. 1000
3. 10
4. 8
5. 4
6. 3000
7. 200
8. 5
9. 840
10. 3.5
11. 0.80
12. 200
13. 0.53
14. 0.003
15. 270
16. 3600
17. 50
18. 0.0005
19. 3
20. 0.0047

Checkup Set 2

1. 10 000
2. 100
3. 1
4. 10 000
5. 1 000 000
6. 8
7. 300
8. 10 000
9. 800 000
10. 150
11. 600
12. 100
13. 0.03
14. 0.2
15. 0.5
16. 4000

Checkup Set 3

1. 1
2. 400
3. 3000
4. 1
5. 4000
6. 15 000
7. 5
8. 1 000 000
9. 6000
10. 480
11. 572
12. 0.4
13. 0.7
14. 5.8
15. 500
16. 8300
17. 0.018
18. 50 000
19. 0.03
20. 0.247

Checkup Set 4

1. 2000
2. 4
3. 1000
4. 47 000
5. 6.6
6. 6.5
7. 4800
8. 0.7
9. 50
10. 0.018
11. 15
12. 5
13. 7
14. 18
15. 27
16. 1600
17. 8000
18. 3

Checkup Set 5

1. 17
2. 2.37
3. 4180
4. 37
5. 43
6. 37 000
7. 1200
8. 500
9. 3700
10. 17 000
11. 4.87
12. 900 000
13. 7 000 000
14. 1 900 000
15. 72.8
16. 3000
17. 238
18. 17 000 000
19. 16 000
20. 28 000
21. 10 000
22. 8000
23. 1500
24. 27
25. 160 000
26. *c*
27. *d*
28. *d*
29. *c*
30. *b*